HIGH ANGULAR RESOLUTION MM- AND SUBMM-OBSERVATIONS OF DENSE MOLECULAR GAS IN M82

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We have observed CO(7–6) , CO(3–2) , HCN(3–2) and HCO^+(3–2) line emission toward the starburst nucleus of M82 and have obtained an upper limit to $H^{13}CN$(3–2). These are the first observations of the CO(7–6), HCN(3–2) and HCO^+(3–2) lines in any extragalactic source. We took the CO(7–6) spectrum in January 1988 at the IRTF with the MPE/UCB 800 GHz Heterodyne Receiver (beam 30″ FWHM, Harris *et al.* 1987). In March 1989 we used the IRAM 30m telescope to observe the CO(3–2) line with the new MPE 350 GHz SIS receiver (beam 9″ FWHM, Harris *et al.* 1989) and the HCN(3–2) and HCO^+(3–2) lines with the IRAM 230 GHz SIS receiver (beam 12″ FWHM, Blundell *et al.* 1988). The observational parameters are summarized in Table 1.

Line	Frequency	Resolution	Telescope	Receiver
CO(7–6)	806.65 GHz	30″	IRTF	MPE/UCB
CO(3–2)	354.79 GHz	9″	IRAM 30m	MPE SIS
HCN(3–2)	265.87 GHz	12″	IRAM 30m	IRAM SIS
HCO^+(3–2)	267.56 GHz	12″	IRAM 30m	IRAM SIS

Table 1: Observational parameters

Fig. 1 shows spectra of the different lines for the offset position 10″ (160 pc) to the SW from the nucleus.

For this position, in the vicinity of the supernova remnant 41.9+58, each of the lines shows a strong, narrow feature at $V_{LSR} \sim 110$ km s^{-1}. The CO(7–6) emission of the nuclear region of M82 consists only of this narrow feature and no emission of the bulk of the molecular gas is seen. The CO(3–2) and HCN(3–2) emission is strongest 10″ SW of the nucleus with the same feature clearly visible. It is also prominent in far-infrared emission lines (Lugten *et al.* 1986, Duffy *et al.* 1987).

Our preliminary results are summarized as follows:

We attribute the emission feature at $V_{LSR} \sim 110$ km s^{-1} to an unusually large star forming complex near the nucleus of M82 with dense gas and a large number

of young, massive stars ($L \sim 10^{10}$ $L_\odot$). Estimates of the size and mass of this most active current star-forming region in M82 yield 5→10″ (80→160 pc) and several 10^7 $M_\odot$. The intrinsic strength of the CO(7–6) line then is a few 10 to 100 K. The excitation of this line as well as of HCN(3–2) and HCO^+(3–2) requires densities $\geq 10^4$ cm^{-3}. The close correlation between CO(7–6) emission and UV-radiation from young, massive stars in galactic sources suggests heating of the CO(7–6) emitting gas by UV-radiation or shocks. The character of this nuclear "hot spot" is not unlike that of the molecular mass concentration near the nucleus of our own galaxy. A more detailed discussion of the nuclear "hot spot" will be published elsewhere (Harris *et al.* 1989).

The HCN and HCO^+ data for other positions show that the central 1 kpc of M82 contains a large amount of dense gas ($n(H_2) \geq$ several 10^4 cm^{-3}). The ^{12}CO(3–2) line flux at all measured positions is weaker by at least a factor of 2 compared to the ^{12}CO(2–1) line. We find a similarly low ratio $I(^{12}CO(3–2)/I(^{12}CO(2–1)) \leq 0.5$ also in a number of galactic molecular cloud complexes. The low ^{12}CO(3–2) to (2–1) intensity ratio cannot be accounted for in simple one component models of the CO emission in molecular clouds. The low ratio may be due to a component of relatively low density ($n(H_2) \leq 10^3$) and low temperature (10 to 20 K) interclump gas where the J=3 level of ^{12}CO is subthermally populated, as in the model for the CO emission of the M17 interface (Stutzki *et al.* 1988). It is then likely that the large ^{12}CO(2–1) to (1–0) ratio is due to temperature gradients in predominantly externally heated clouds (see discussion in Young and Scoville 1984). A more detailed discussion will be presented in Wild *et al.* .

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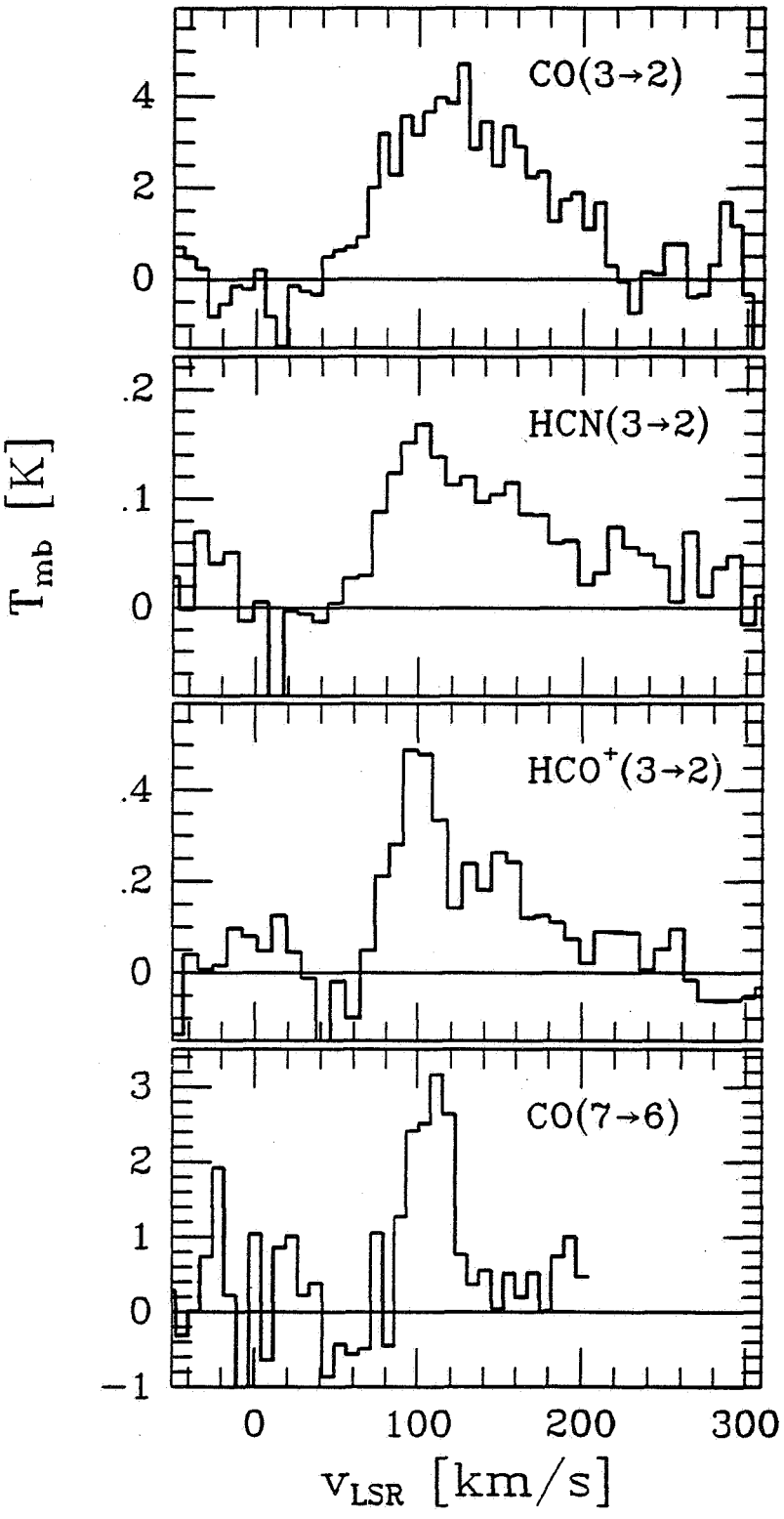

Fig. 1 Spectra of the nuclear "hot spot" of M82, 10″ (160 pc) SW of the nucleus